

# Repoint track switch wheel-rail mechanical interface analysis

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**ABSTRACT:** Repoint is a new concept for track switching developed at Loughborough University. Through a novel locking arrangement it allows parallel, multi-channel actuation and passive locking functions, providing a high degree of fault tolerance. The concept, based around a stub switch, offers several features that current designs are unable to achieve. The aim of the work presented in this paper is to evaluate the dynamic interaction forces due to the passage of rolling stock over the switch and, particularly, the area of the stub rail ends, in comparison to a conventional switch. Specific behaviour and load transfer conditions from one rail to the other at the joint are analysed, as well as long term wear conditions of the rails. These evaluations are undertaken by means of dynamic simulations, leading to design refinement of the stub rail ends.

## 1 INTRODUCTION

The novel Repoint concept comprises a bank of in-bearer type electro-mechanical actuators, featuring integral passive locking elements, which allows multi-channel redundant actuation of route setting. The key aspect of the concept is that individual actuators can fail but the overall system will still set routes (Bemment, S. D. et al. 2013a,b). Figure 1(a) shows the main Repoint switch elements and Figure 1(b) shows the interlocking rail ends. On the rail ends, the chamfer in the horizontal plane locates the rails laterally, meaning the moveable rails require lifting to disengage this chamfer before they can be moved horizontally. The concept allows for some longitudinal movement in the rails in the same way an expansion switch operates, thus accounting for thermal movement. The chamfer in the vertical plane gives a smooth transfer of load from one rail to the other and reduces the chance of debris fouling the interface.

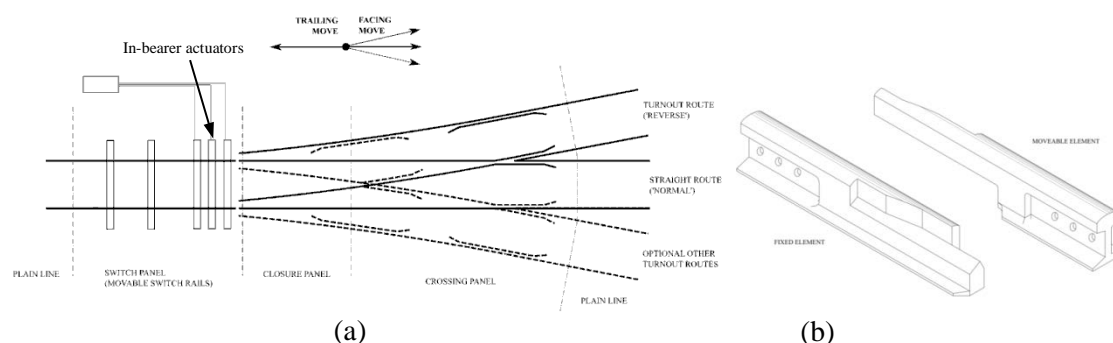


Figure 1. (a) Repoint stub switch general arrangement with electro-mechanical in-bearer type actuators, with most sleepers/bearers omitted for clarity. Switch panel features rail moveable elements. (b) Interlocking rail ends. Moveable elements lie on in-bearer type actuators in the switch panel.

## 2 DYNAMIC WHEEL-RAIL FORCE ANALYSIS

The Repoint system removes the need for a classical switch/stock rail assembly that is well known to generate undesired dynamic effects due to the geometrical change in rail shape and the resulting rapid changes in contact conditions of the wheels. Instead, a constant full rail section is used in the area of the switch panel while the stub rail joints are introduced further along towards the heel (Fig. 1(b)). This concept is expected to improve the dynamic forces behaviour in comparison to a conventional switch panel.

A key aspect of the development involves the design of the joints (rail ends) to ensure smooth wheel-rail contact running. Through results from the multibody simulation software Vi-Rail, this improvement has been quantified and the specificities of the contact conditions established (Bezin, Y. 2016). Figure 2 presents simulation results of the lateral ( $F_y$ ) contact forces comparing Repoint to a reference UK CEN56 CV switch arrangement described in (British Standard 13674-2, 2006). Note that this switch is of short length and slow diverging speed (40km/h), generating significant steering forces (curve radius = 245m). The vehicle model is a UK Diesel Multiple Unit class 170 (DMU170). The aim is to investigate leading bogie and carbody behaviour.

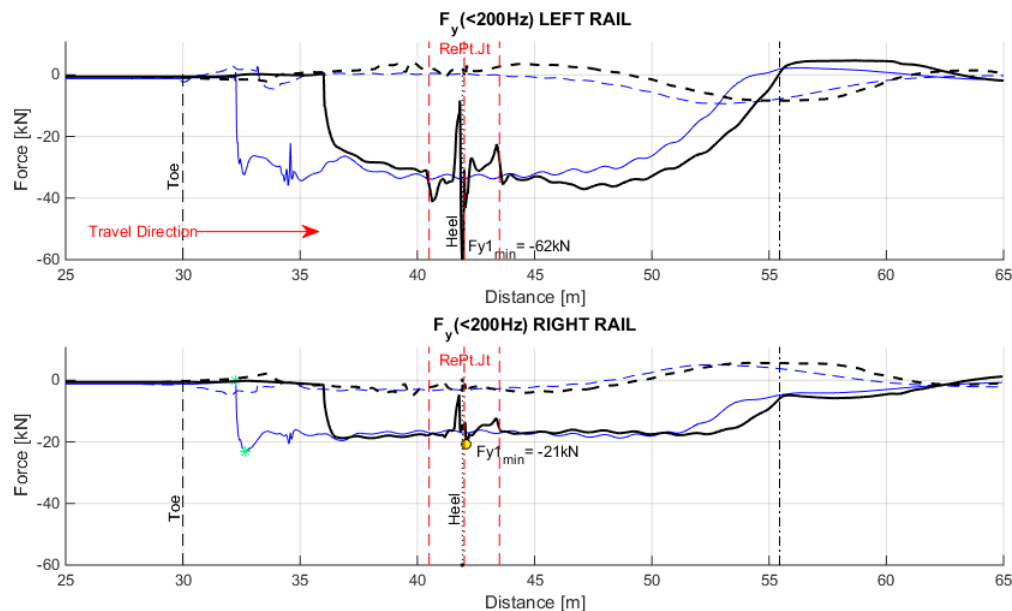


Figure 2. Lateral guiding forces on the wheels (negative means gauge spreading forces on rails). Repoint (black) vs. CEN56 CV (blue). Leading axle (solid) / trailing axle (dashed). Outer rail (left rail) results on the top row and inner rail (right rail) on the bottom row.

The leading wheelset generates the majority of the steering forces, with the outer wheel/rail experiencing larger forces than the inner wheel/rail due to large lateral offset (Fig. 2) and flange contact. The CEN56 CV force profile is characterised by sharp rise in lateral force at switch toe and imposes a dynamic force disturbance just before 35m due to change in contact from stock to switch rail. This is a typical behaviour in conventional S&C often leading to associated local geometry degradation affecting the safe and reliable operation of Point Operating Equipment, as well as generating incidental costs in managing wear and fatigue of the stock and switch rails.

The Repoint switch on the other hand shows a slower and delayed build-up of lateral forces about 6m after the toe, eventually rising to the equivalent quasi-static equilibrium forces once in the full switch curve radius. The Repoint stub joint necessarily needs to be straight and therefore includes a local chord offset introduced in these simulations as an added irregularity, which leads to further dynamic force disturbances as the axles are forced to steer through the chord direction. This is indicated in Figure 2 in the area between the vertical dashed red lines. There is a slight rise of force before the joint, which then decreases before it goes back to normal quasi-static conditions.

Additionally, in the outer rail, the joint (RePt.Jt) causes another very short transient of higher magnitude with a sudden drop of lateral force and then a reciprocally high value. This is due to the local transition of contact from the moveable element to the fixed element of the joint, while lateral flange contact is sustained and the expansion gap suddenly appears before the wheel. The wheel then travels further against the rail until it makes contact with the end of the fixed element. Improved designs of the stub ends should prevent this behaviour to avoid the spike seen.

Figure 3 shows simulation results of the vertical forces. The Reprint switch demonstrates a smoother transition in load from toe to heel. However, both designs show transient effects either under the switch-stock rail assembly or the Reprint joint. Figure 4 represents lateral displacement (top) and angle of attack (bottom) of the leading axle and trailing axle for Reprint and CEN56 CV. The lateral offset of the leading axle is noticed from the toe onwards but this effect is delayed and more progressive for the Reprint design. This more gradual change in wheel behaviour is observable from the leading axle angle of attack steadily increasing towards the heel.

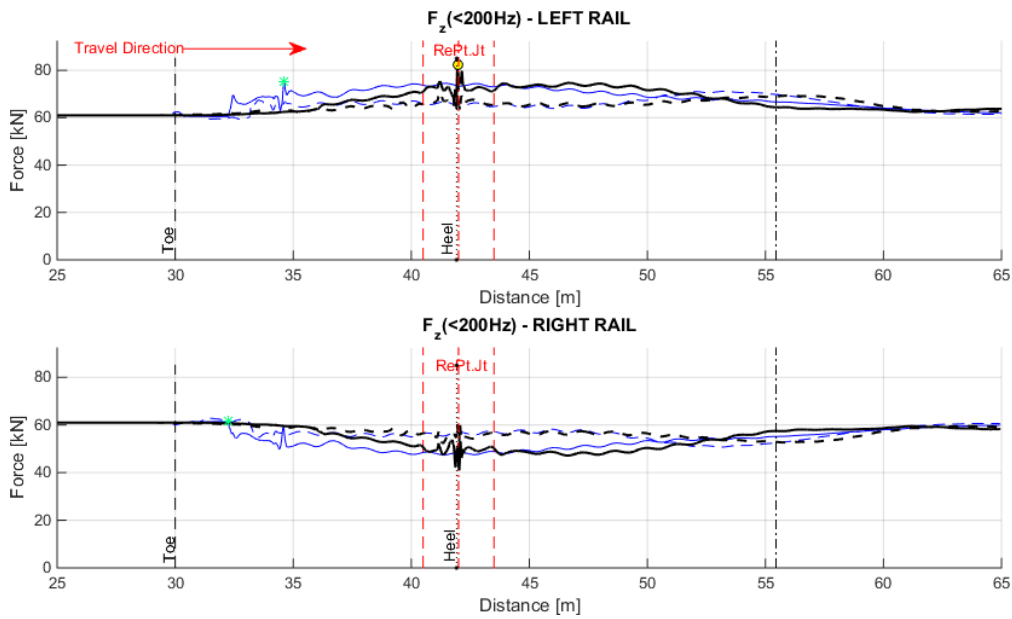


Figure 3. Vertical forces on switch rails. Reprint (black) vs. CEN56 CV (blue). Leading axle (solid) / trailing axle (dashed). Outer rail (left rail) results on top row and inner rail (right rail) on the bottom row.

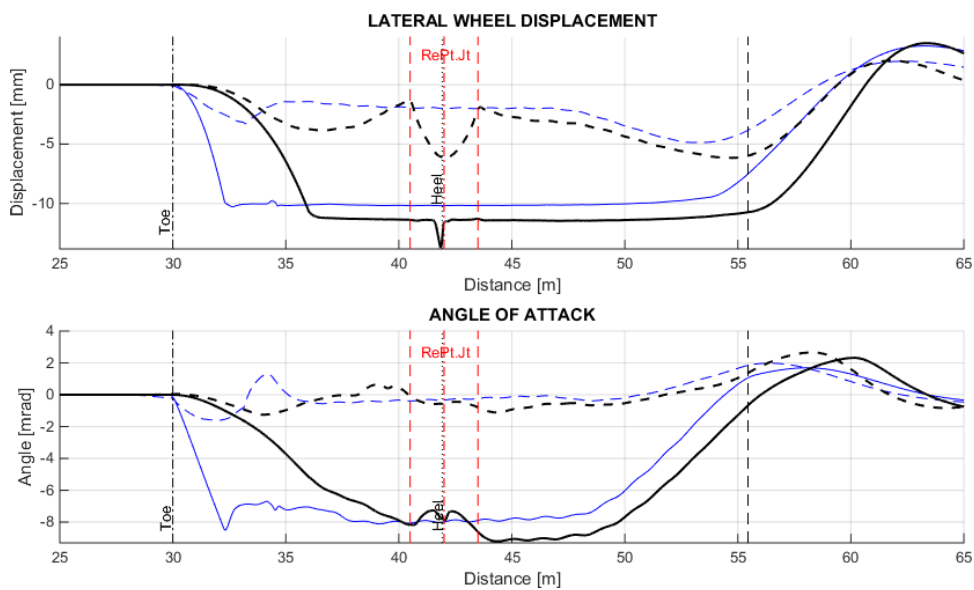


Figure 4. Axle lateral displacement and angle of attack. Reprint (black) vs. CEN56 CV (blue). Leading axle (solid) / trailing axle (dashed).

Some local change of angle of attack is also visible in the area of the joint chord offset, which directly translates to the lateral force disturbance described previously. This effect will also be discussed with respect to contact wear in the following section. On the top plot the lateral movement of the axle locally at the joint is seen with an added 2 to 3mm lateral displacement over a very short duration, corresponding to the behaviour described previously.

Figure 5 represents the Hertzian contact stress plots. For CEN56 CV, the highest contact stresses are observed during change of contact from stock to switch rail (between toe and <35m). The high transient nature of the contact conditions, i.e. multiple and sudden contact jumps, leads to very high values (in the order of more than 3GPa, equivalent Hertzian pressure) on the left rail. This condition may lead to fatigue failure and deformation of the switch rails at their thinnest and weakest part. On the other hand, the Repoint switch demonstrates a lower value at start due to the use of inclined rails, and a much smoother transition in the same area, maintaining low contact pressure throughout the switch panel. The reason being normal crowned rail shape is maintained throughout the switch panel and optimum wheel-rail contact conditions are ensured.

However, there is an exception with the joint, where very high values are seen under the transient load over short distance/duration. Note that beyond the heel, as previously explained, both systems lead to inevitably high quasi-static steering forces in the curved section of the turnout in this very short switch example. This would indicate that the current design is leading to acceptable contact conditions. Nevertheless, tangential contact conditions need to be analysed in more detail to establish the level of wear or rolling contact fatigue to be expected, especially at the joint.

Figure 6 shows the  $T\gamma$  output indicating the level of energy spent within each contact under the action of the creep forces and creepages. The area of output normally associated with rolling contact fatigue (RCF) for a grade 260 rail is highlighted in yellow between 20N and 160N (peak value estimated at 65N is indicated with a horizontal semi-dashed line) (Burstow, M.C. 2004). The white background area above 160N is entirely dominated by wear.

On the left (high) rail, high wear is noticed due to the leading wheel being in flange contact through the switch curve. On the CEN56 CV, high wear will occur earlier near the toe and it will be sustained at a high level, mostly because of the vertical rail. On Repoint the onset of wear is delayed until 5m after the toe, but also occurs at a high level. The passage over the joint and the chord offset generate a further local peak of wear energy. Note that both trailing wheels on both designs have a much lower energy output on the high rail and might be in a region triggering RCF.

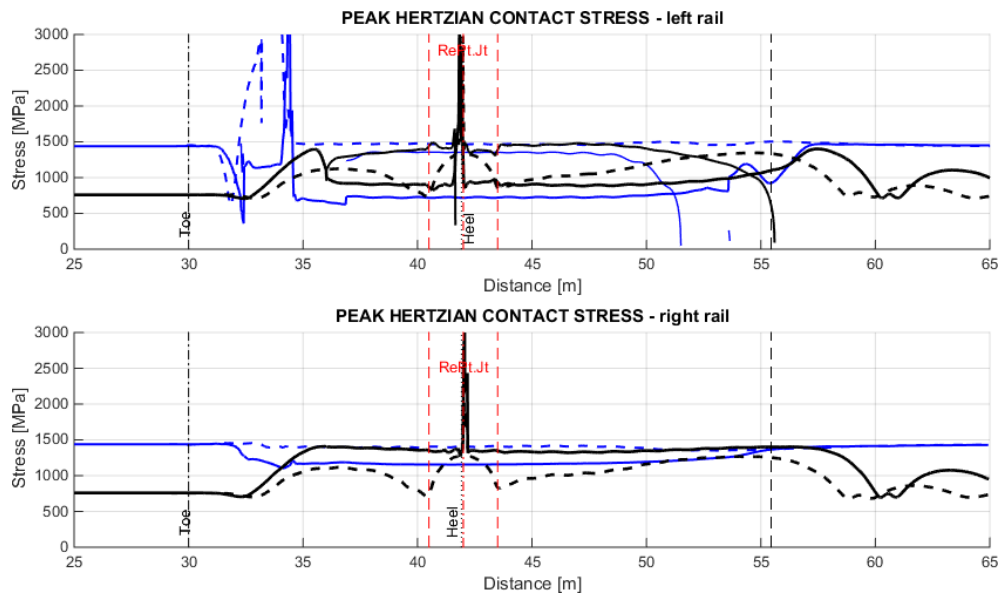


Figure 5. Peak Hertzian contact stress. Repoint (black) vs. CEN56 CV (blue). Leading axle (solid) / trailing axle (dashed). Outer rail (top row) and inner rail (bottom row).

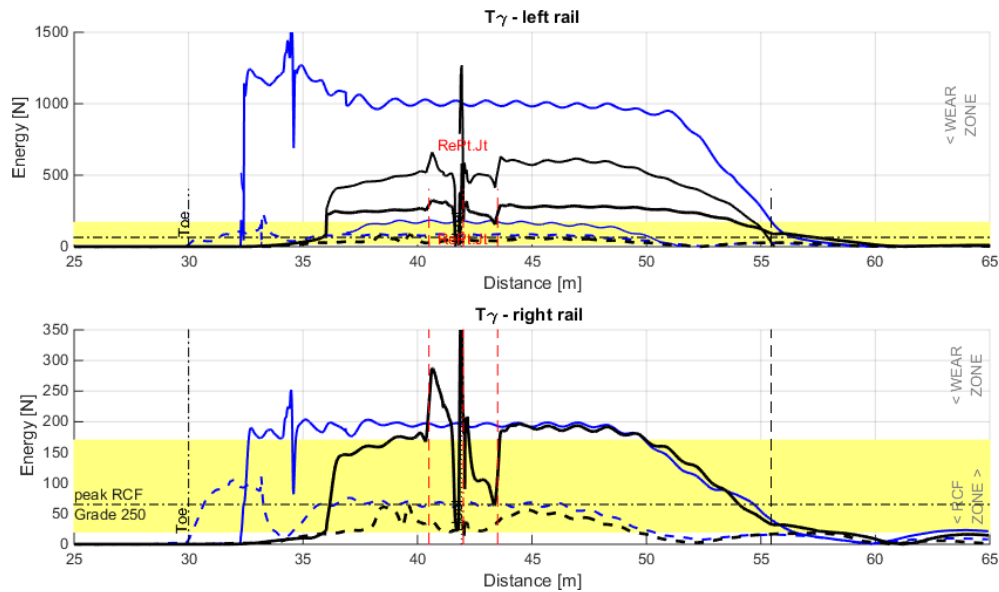


Figure 6.  $T\gamma$  energy output, indicating wear (white background) and RCF (yellow background) zones. Reprint (black) vs. CEN56 CV (blue). Leading axle (solid) / trailing axle (dashed). Outer rail (top row) and inner rail (bottom row).

On the right (low) rail, the energy value is much lower at the limit of wear and RCF. Here again the CEN56 CV design shows an early rise towards the wear region, while this is delayed on Reprint. The passage over the joint and the chord offset also leads to either an increase of  $T\gamma$  (1<sup>st</sup> part of chord offset) or a decrease towards RCF region (2<sup>nd</sup> part of chord offset). The rapid change of contact conditions in the joint centre also generates strong transient effects.

### 3 INITIAL RESULTS OF WEAR ANALYSIS

In order to better understand the long term behaviour of the joint, wear analysis was performed using the VI-Rail wear toolkit based on Archard wear theory (Archard, J.F 1953). A loop simulates a mix of traffic in the diverging direction. The traffic mix includes 2 passenger units and 2 locomotives (80% full traction and coasting), as well as 9 freight wagons with a wide range of representative measured worn wheel shapes. Figure 7 presents preliminary results of this study.

On the left rail the wear can be seen on the crown of the rail and in the gauge corner, with a spike on the edge of the female part of the joint. On the right rail, the contact is wearing out the top crown of the rail as expected in comparison to normal application of expansion joints. Further analyses will be carried out to investigate the performance of the joint over time considering a mix of traffic in the through and diverging routes.

### 4 CONCLUSIONS

The benefits of Reprint have been demonstrated at the initial part of the switch between the toe and the heel. Beyond this section, the quasi-static curving behaviour of the vehicle through the tight curve is dominant and not compliant with maintenance requirements of the rail (high rail wear or RCF) and geometry (e.g. tamping). However, the inclined rail design, constant rail cross section and smooth entering into the switch curve provide an opportunity to improve the wheel-rail contact conditions, and reduce transient loads and associated rail damage. The design of the Reprint joint is crucial to the success and evolution of the innovation. The current version of the concept already shows different advantages over traditional track switching solutions, whilst presenting several opportunities for improvement.

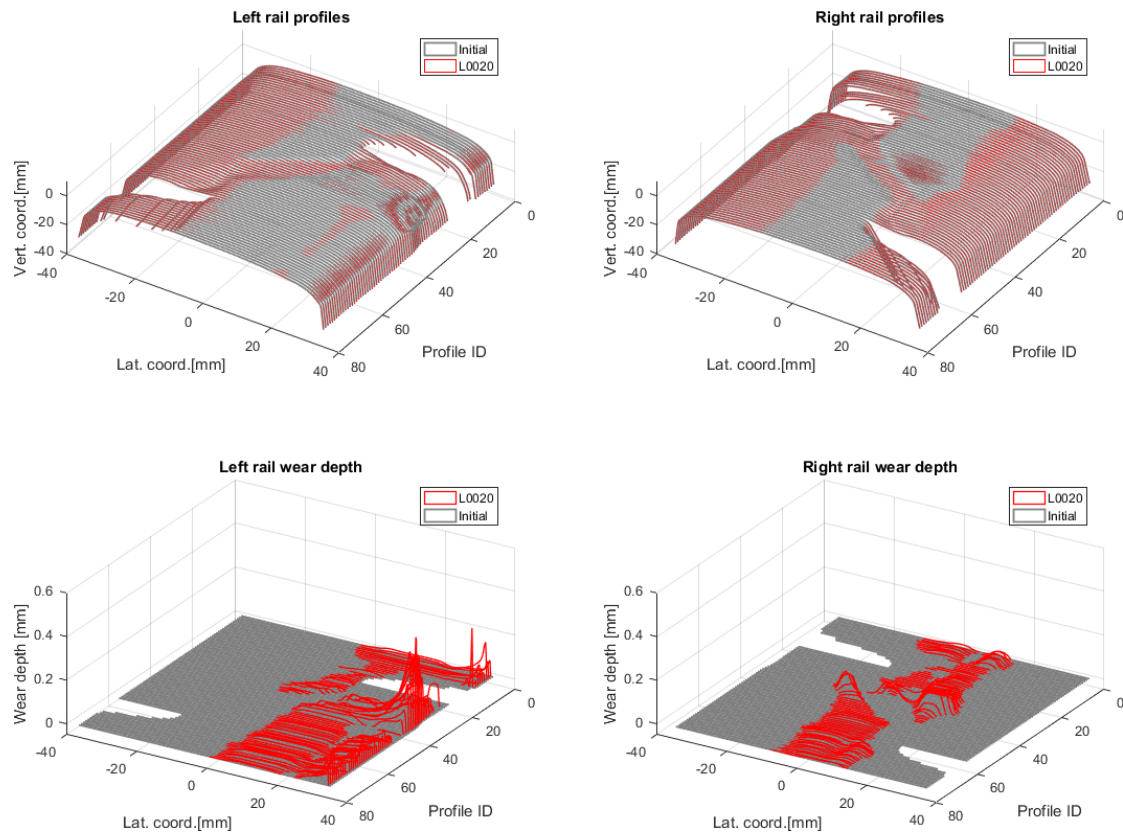


Figure 7. Wear analysis of Repoint joint on high rail (left) and low rail (right) showing initial and worn profiles (top) as well as calculated wear depth (bottom). Gauge side of profile is in the negative lateral coordinates. Profile ID is in increasing order of appearance (not equidistant in reality).

In particular, it appears that for short switches and tight radius curves, the expected flange contact of the leading wheel with the rail gauge corner is not compatible with the current joint design. This condition leads to lateral transient loads and local damage mechanisms of the joint: high deformation in load transfer and wear. Differential wear is also likely to occur between the moveable and fixed part of the joint depending on the mix of traffic between through and diverging route(s). Rail wear analysis is on-going work to properly estimate the wear process of corresponding elements of the switch panel.

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